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ABSTRACT

The purpose of this investigation was to identify the changes in (n=8) inservice teachers' conceptions or knowledge structures of mathematics and subject specific pedagogy as the teachers participated in a two-year pilot professional development program and began teaching middle school mathematics. Data collection consisted of a questionnaire, interviews, and a unit work sample. Teachers in the study had not previously taught secondary mathematics. Results showed that teachers' own experiences in learning mathematics indicated these inservice teachers had been taught mathematics in the early grades by worksheets, drill and practice, memorization, and flash cards. Although participants reported feeling more confident and able to present mathematics to students using a variety of approaches, several statements and videotapes of their teaching presented conflicting views. The conceptions/knowledge structures of the teachers regarding mathematics teaching did not change significantly. (MKR)

Professional Development for Mid-level Mathematics

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Professional Development for Mid-level Mathematics

Introduction

Reforms in mathematics education, the implications of the National Council of Teachers of Mathematics (NCTM) Curriculum and Evaluation Standards (1989) and Professional Standards (1991), and the Carnegie Council's Turning Points: Preparing American Youth for the 21st Century (1989) have renewed an emphasis on increasing the quality of teacher preservice and inservice education programs for the middle grades. The Carnegie Council recommends that "teachers in the middle grade schools should be selected and specially educated to teach young adolescents and should receive a supplemental endorsement upon completion of this training" (pg. 7). The debate about teacher licensure requirements continues to pose a problem in many states. State licensing agencies assure the public that students will be taught by individuals who have knowledge of specific subject areas and pedagogy for teaching that subject as well. These teachers will, therefore, be more effective teachers than those who do not possess such background.

Perhaps the most contentious debate in teacher licensing regards the preparation of middle school/junior high teachers. Today's mid-level teachers are initially prepared either by departments of secondary education that emphasize subject matter depth or by departments of elementary education that focus on teaching young children. The large majority of mid-level teachers have no special preparation for teaching or working in other ways with young adolescents. To compound the problem, the majority of teachers entering the profession do not have the option of preparing specifically for the middle level (McEwin, 1992).

The NCTM's Curriculum and Evaluation Standards (1989) recommends that increased attention be paid to developing students' understanding of problem solving, statistics, probability, algebra, geometry, and patterns and functions at the middle level. Currently, in many states, elementary teachers licensed to teach all subjects grades K-9 are being asked to teach middle school mathematics up to and including algebra. These teachers must not only possess considerable knowledge of mathematics, but they must possess a repertoire of pedagogical skills from which they can select the most appropriate way of presenting concepts to students (McDiarmid, Ball, & Anderson, 1989). Shulman (1986) has suggested that teachers need more than an understanding of mathematics, they must know how to translate mathematics to students in an understandable, conceptual manner. Many teachers licensed to teach all subjects in grades K-9 are simply not prepared to teach this type of mathematics. Middle school mathematics teachers "are not receiving adequate preparation in either mathematics content or methods of teaching mathematics." (Trent, 1987)

As a result of these interests and concerns, a summer program supported by the Dwight D. Eisenhower Mathematics and Science Improvement Program, was designed for teachers licensed in subject areas other than mathematics or licensed at the elementary level to specifically prepare them to teach middle school mathematics.

Purpose of the Study

The purpose of this investigation was to identify the changes in inservice teachers' conceptions or knowledge structures of mathematics and subject specific pedagogy as they participated in a two-year pilot professional development program and began teaching middle school mathematics.

Three questions of interest guided this research:

1. What conceptions or knowledge structures of mathematics did the inservice teachers possess before the program?

2. What conceptions or knowledge structures of subject specific pedagogy did the inservice teachers possess before the program?

3. What changes, if any, occurred in the teachers' mathematics and pedagogical conceptions or knowledge structures during the two-year program?

For the purpose of this study, knowledge structure refers to the knowledge an individual possesses and the manner in which this knowledge is organized. Mid-level is defined as grades four through ten.

The Program

The Dwight D. Eisenhower Mathematics and Science Education Improvement program supported the development of a summer program at a western university to prepare teachers for teaching mid-level mathematics in a manner consistent with current recommendations and reform measures. The program specialized in preparing mathematics teachers to teach interdisciplinary and integrated lessons with an activity- and lab-based teaching model. Emphasis was placed on teaching mathematics for understanding, use of appropriate technology, applications, and problem solving. The program provided full tuition support for the first summer and half tuition support for the second summer. A third summer was available for teachers who wished to complete 15 additional quarter hours to receive a Master's degree in mathematics education. This program consisted of:

Twelve quarter hours of mathematics:
- Problem Solving
- Math and Technology
- Math for the Mid-level I
- Math for Mid-level II

Fifteen quarter hours of subject specific pedagogy:
- Math Curriculum for the Mid-level
- Materials Development
- Authentic Assessment
- Advanced Strategies in Teaching Mid-level Math
- Integrating Math-Science-Technology

Three quarter hours of practicum:
- Math Teaching Practicum

These courses provided essential preparation in mathematics knowledge as well as in the teaching of mathematics. Upon completion of the program, participants received a mid-level mathematics specialist certificate and were encouraged to take the Praxis mathematics content test required for an endorsement for teaching mathematics up through algebra.

Design

The target population for the program included teachers who were licensed in subject areas other than mathematics at the secondary level or who were licensed at the elementary level. Participants were required to teach one mathematics course during the school year following the first summer session. The sample chosen for this study consisted of eight inservice teachers who were part of a cohort group of 21 inservice teachers participating in the program. These eight teachers were chosen because they had not taught mathematics above sixth grade prior to the program. Five females and three males were selected. Five of the participants were licensed in elementary education and three possessed secondary licenses in other subject areas including science, language arts, and physical education. The average number of years of teaching experience for the participants was nine years. Seven of these teachers had taught mathematics in fifth and sixth grades. The remaining teacher had been teaching first grade.

Data collection utilized three sources of data. The initial data source was a questionnaire consisting of two parts and administered at the beginning

of the first summer session. The first part of the questionnaire requested general information about the teacher, including:

1. How many years have you been teaching?
2. What type of certification do you possess?
3. Describe the subjects/levels that you taught this past year.
4. Describe the mathematics that you studied/learned in the following grades: 1-3, 4-8, 9-12, 13-16, since then.
5. Describe your experiences in learning mathematics.
6. Describe how you believe students learn mathematics.
7. Describe your best mathematics teacher(s).
8. Describe your worst mathematics teacher(s).

The second part of the questionnaire asked the participants:

1. What is mathematics?
2. What topics/concepts/themes/processes comprise mathematics?
3. If you were to use these topics/concepts/themes/processes to diagram mathematics, what would it look like?
4. What are the important elements or concerns in teaching mathematics and what would a diagram look like?

When the questionnaire was administered at the end of the second summer (14 months later), a fifth question was added:

5. Do you think that your views have changed over the past year? If so, how?

The second source of data was an interview conducted by the researchers at the end of the second summer. The participants were interviewed and asked to compare their original response on the second part of the questionnaire to their final response, describe what they had learned in

the program, and describe how they felt about teaching mathematics after completion of the program.

A third source of data consisted of a unit work sample. The teachers were required to teach a 12- to 18-hour unit and complete a work sample consisting of unit goals, instructional objectives, lesson plans, pupil data, analysis of teaching and learning, and three videotaped lessons. The researchers searched for patterns within the work samples including lesson videos that were consistent with the participants' responses from the questionnaires.

Results and Discussion

Analysis of the data collected at the beginning of the program regarding the teachers' own experiences in learning mathematics indicated these inservice teachers had been taught mathematics in the early grades (grades one through eight) by worksheets, drill and practice, memorization, flash cards, and "lots of individual written practice." Several remembered memorizing the addition facts to 20 and the multiplication facts to 12. Half of the teachers remembered completing worksheets in grades one to three and "more worksheets" in grades four through eight. Seven of the teachers had not taken more than two mathematics classes in high school, only completing through geometry. The other teacher had taken mathematics in high school through pre-calculus. All of the teachers had taken at least college algebra. Two teachers had taken the beginning term of calculus. When asked to describe the mathematics courses they had taken since graduation from college, five of the teachers had taken no mathematics. The other three teachers had taken only one other course in mathematics (Math and the Mind's Eye).

With respect to their experiences in learning mathematics, half of the teachers had positive experiences.

> I always loved doing math. I never really had trouble. The experience seemed easy through high school.

> I've basically had very positive experiences in math. I learned to do a lot of mental math and always picked up on concepts quickly. Most of my math teachers were very good and I've usually enjoyed all my math classes.

The other half of the teachers had not thought their experiences in mathematics had been as positive.

> I never took it (mathematics) seriously when in high school or college. I didn't believe I needed to know it very well and was bored in my early classes. I didn't see any use or relevance to me. Teachers didn't encourage girls to excel in math and I didn't work too hard at learning math. I didn't find learning math was interesting or fun either.....rather boring.

> Math was avoided at all costs in high school and college. This was not an area of interest or concern... .

When asked how they believed students learned mathematics, five of the teachers stated they believed students learned best by using visuals, hands-on activities, concrete models, and making the concepts relevant to students' lives. They also listed ideas such as exploring, discussing, discovery, thinking, building, writing, drawing and group work as ways students learn. The other three teachers believed that students learned best by practice and repetition. "I believe students learn primarily through practice." "Repetition is important."

Characteristics of the participants' best teachers included: fun, bright, caring, confident, willing to help, personable, concise ("established pattern of: teaching, assignments, tests"), and gave individual instruction. Only one teacher mentioned her best teacher in terms of his teaching of mathematics.

> He (algebra teacher) made us write out every step even when we wanted to take short cuts. This was very helpful when the algebra got longer and harder.

The participants stated their worst teachers possessed characteristics such as: never explained, had to do the mathematics "their way," impatient, late to class, boring, insisted on memorization of all information, and "same thing day after day." Interestingly, the same three teachers who believed that students learned best by practice and repetition also listed the characteristic of their worst teacher as a teacher who provided "drill, drill, drill" or " 'This is the way you do it-memorize it!'."

The results on the second part of the questionnaire (administered at the beginning of the program and at the end) are reported in terms of the initial questions guiding the investigation.

Knowledge Structures of Mathematics

The responses from the initial questionnaire indicated several different types of responses from the inservice teachers. In response to the question "What is mathematics?", six of the inservice teachers related mathematics to the study of numbers.

> Mathematics is a system of study that uses numerals (numbers that stand for objects, for counting or for identification).

> It (mathematics) is working with numbers and symbols used everyday to explain various concepts or activities in life around us.

Two of the inservice teachers related mathematics to a way of using logic to order the world. Another inservice teacher related mathematics to a way of thinking:

> Mathematics is a method or logic of problem solving. It is an investigation into questions we have about our world and is a way of thinking or "order of thinking" to try to organize these questions.

When asked what topics, concepts, themes or processes comprise mathematics four of the teachers listed specific topics of mathematics including basic skills, addition, subtraction, multiplication, division, geometry, estimation, fractions, decimals, percents, probability, statistics, graphing and algebra. Two of these teachers diagrammed the topics using a topic listing structure. Both listed "numbers" at the top and forked to include the other topics, with no apparent levels. The other two teachers used pie diagrams, dividing the pie into proportional pieces. Interestingly, none of the teachers listed or diagrammed any specific topics or concepts in mathematics higher than what would be taught in first year algebra.

Two of the teachers associated the topics of mathematics in a broader sense to the world around us and related that perception through a diagram connecting mathematics and the world. "It (mathematics) should be a process that prepares all of us for the present technological age." One teacher stated that he "was not aware of anything that math is <u>not</u> comprised of. Mathematics pervades man's existence and allows our existence as we know it." Figure 1 displays this inservice teacher's diagram.

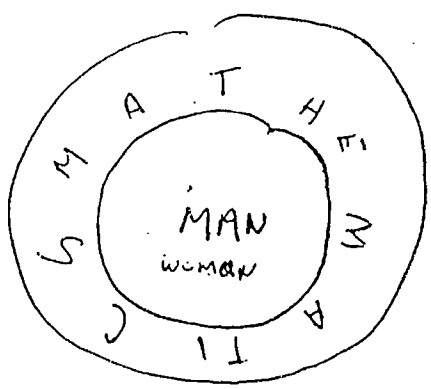

Figure 1

Two teachers diagrammed mathematics in a web-like fashion (see Figure 2). They included mathematics in other subject areas and listed the more general terms used in mathematics such as critical thinking, patterns, and problem solving.

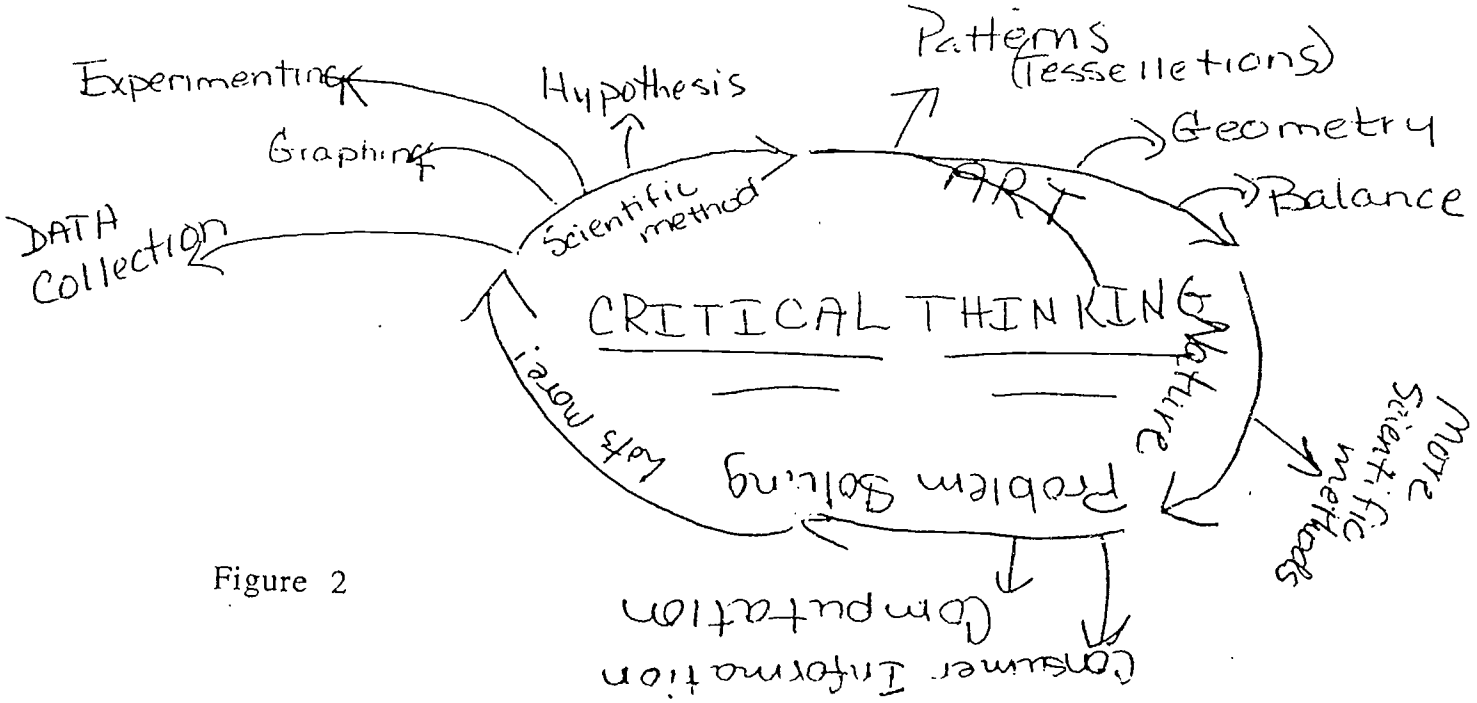

Figure 2

Knowledge Structures of Mathematics Teaching

In response to the question concerning the important elements or concerns in teaching mathematics, four of the inservice teachers believed that one of the most important aspects of teaching mathematics was to make mathematics relevant to the students' lives.

> (Mathematics teaching needs to be) relevant to students needs, knowledge and abilities. Most of what is taught is taught in a context either foreign or of little use to the student at that particular time. They learn when it is of use to them, when they can see the benefit to them of learning the material. We do a poor job of this in mathematics education.

The teachers also listed other important aspects of mathematics teaching including: integration with other subject areas, developing positive attitudes towards mathematics, teacher knowledge and attitude, time on instruction, applications, providing developmentally appropriate presentations, providing hands-on activities for students, and making the students feel comfortable about mathematics. One of these teachers discussed assessments, stating: "assessments based on performance, more than paper and pencil testing" are an important concern of teaching mathematics.

The teachers were also asked to diagram the important aspects of mathematics teaching. Six of the teachers drew diagrams similar to their diagrams of mathematics, listing specific topics or concepts that are taught in mathematics. The other two teachers drew more complex models of mathematics teaching including students, teachers, mathematics, other academic disciplines and technology (see Figure 3). Interestingly, the teachers tended to use the same type of diagram for both mathematics and mathematics teaching. For example, one teacher used a pie chart for his diagram of mathematics and for his diagram of mathematics teaching.

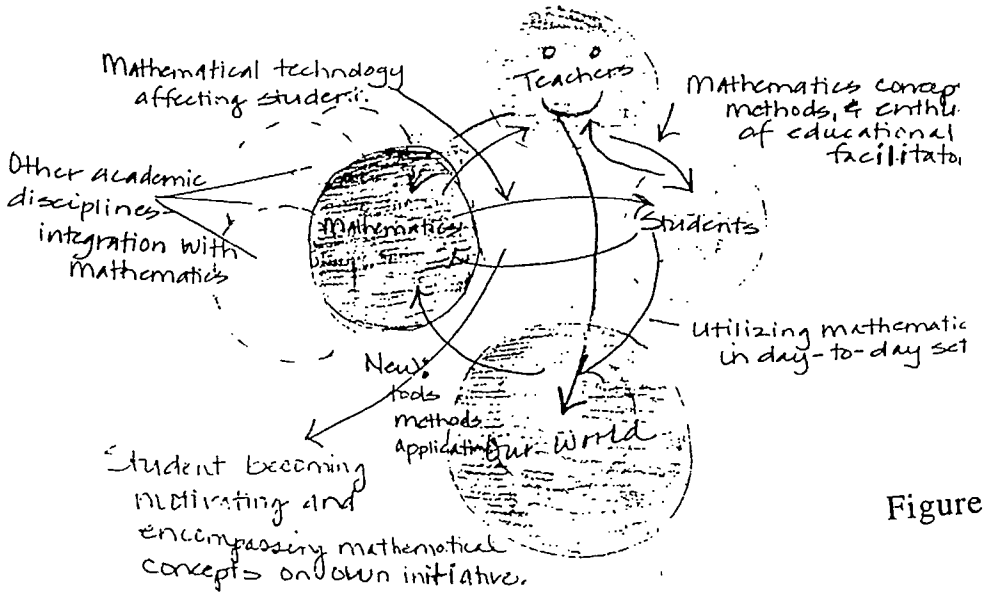

Figure 3

My teaching of mathematics diagram!

Changes in Knowledge Structures

Analysis of data at the end of the program indicated that these teachers' views of mathematics and its teaching had not changed significantly. The teachers who had previously thought that mathematics is best learned by practice and repetition still held this view, however, they had also added that students needed hands-on activities.

> I think students learn in a variety of ways. Lots of practice for some students, where others need to be challenged along another line. It needs to be relevant to the student with a concrete base before going to the abstract. The use of hands-on materials for concepts.

Furthermore, these teachers held the belief that mathematics was the study of numbers and how those numbers related to everyday life. When listing the topics, concepts, themes and processes of mathematics, the same type of listings were made. The same two teachers who had listed the specific topics/concepts of mathematics at the beginning of the program drawing a diagram listing these topics, had changed their diagram. Instead of the diagram being a listing of the specific topics, they had drawn a continuum of the specific courses of mathematics, such as that in Figure 4.

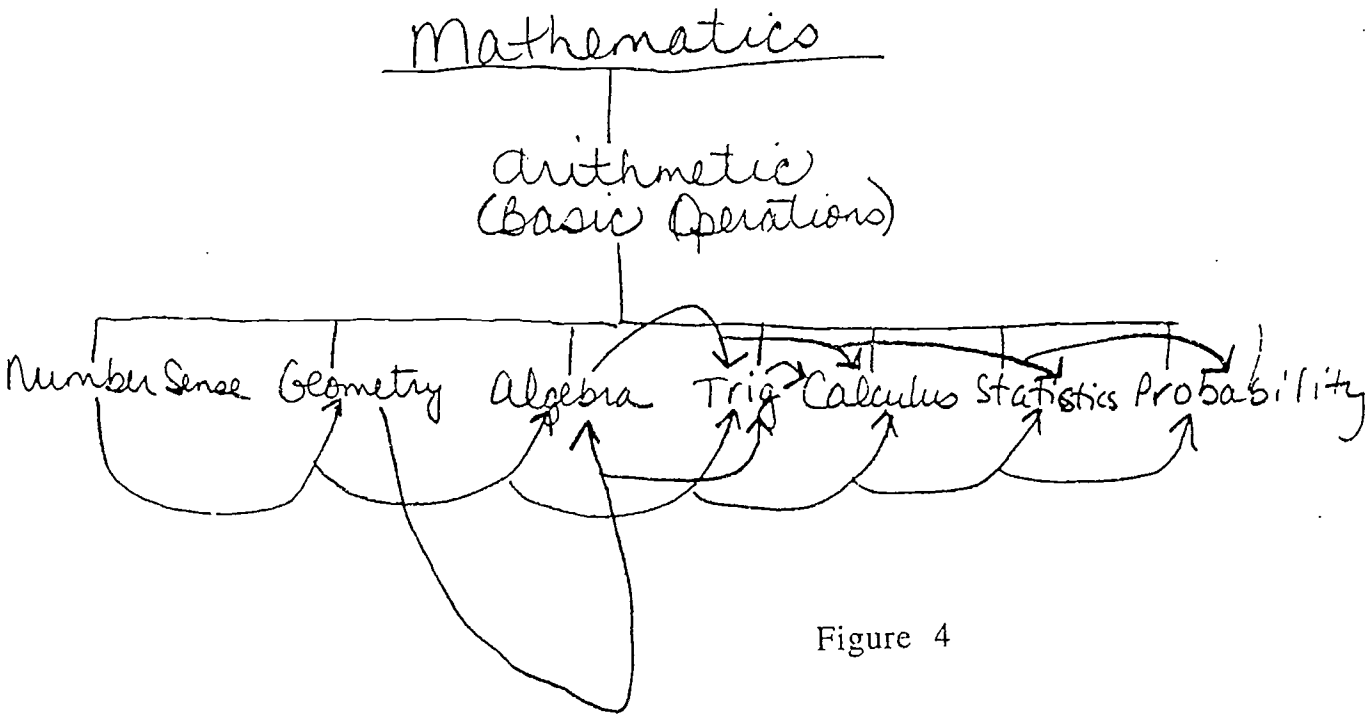

Figure 4

One difference noted among the diagrams was that the teachers now tended to include the NCTM standards of reasoning, communication, problem solving and connections as part of mathematics. Several of the teachers used these standards as a focal point of their diagram as presented in Figure 5. Two other important differences that were listed by the teachers, that had previously been omitted, were technology and integration. Four of the teachers specifically listed technology as being a major topic of mathematics. The teachers also included "integration" in their pictures of what was important in mathematics. When asked about what the teachers meant by integration, most of them stated that integration would include making a connection between mathematics and other subject areas (art and science).

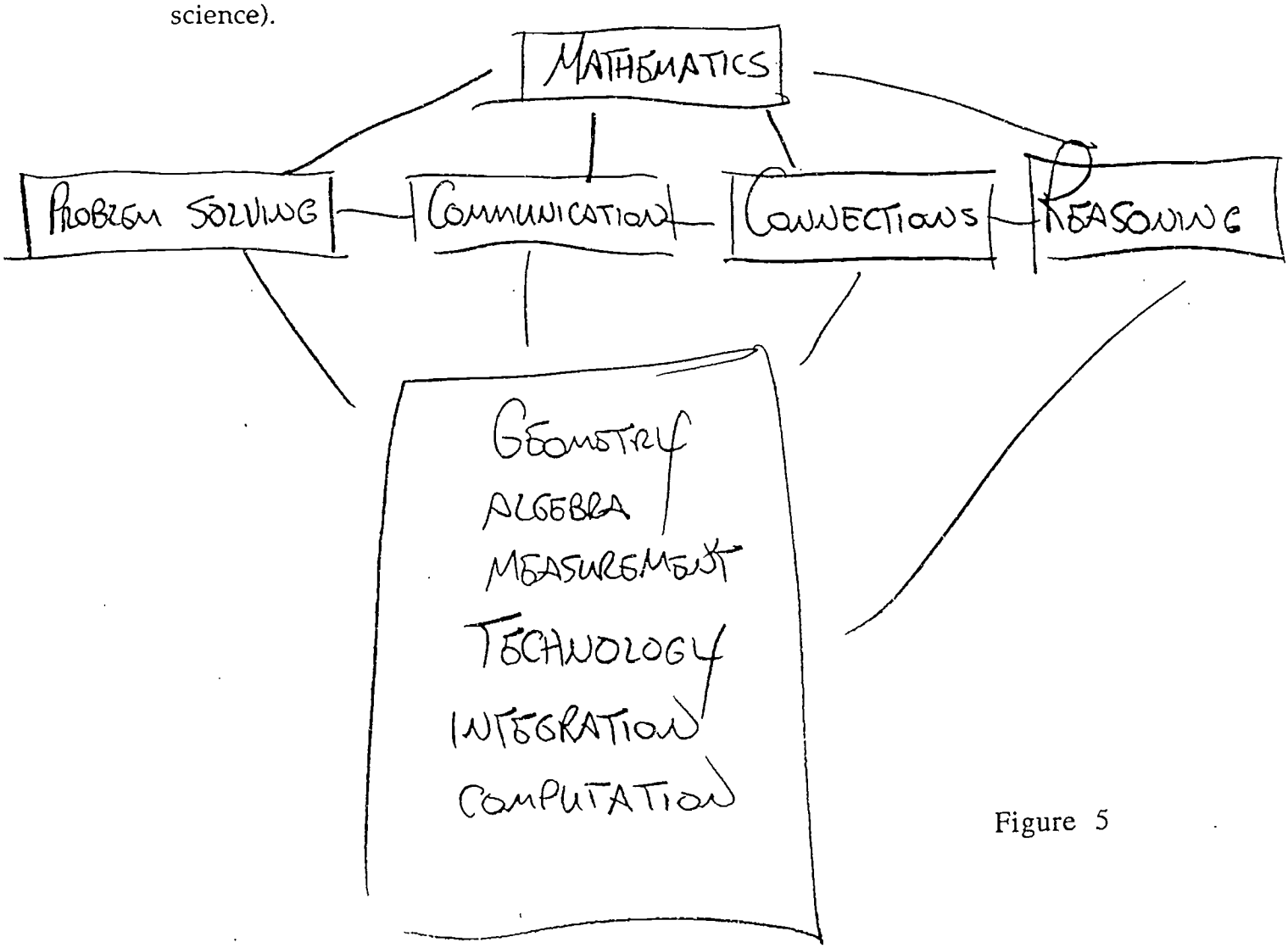

Figure 5

Most of the teachers continued to state that making mathematics relevant to the students' lives and providing hands-on, concrete examples were important concerns in teaching mathematics. At the end of the program two noted changes had occurred in the teachers' thinking about teaching mathematics. First, several stated that having a teacher that was knowledgeable about mathematics was a central concern.

> Most important is that teachers who are teaching math, especially in the middle school and high school levels, be trained in math. Students are easily turned off to math and a teacher not properly trained could turn them off. With training, a teacher could reach a student. I think math teachers should also be required to keep current on their math skills and learn new teaching approaches.

The teachers were also concerned about the students' perceptions of mathematics. Several expressed concern similar to this teacher's comments:

> My main concerns are that students not feel badly about math and their skills in math. Math can be such a scary, frustrating experience for many kids, that they turn off and/or tune out, but if they can experience math and aren't afraid to take risks in math due to their fears of grades then they can realize and maybe actually develop a level of self esteem that will encourage them to explore mathematics.

During the interviews, the participants were asked how they felt about the program and what important concepts/ideas they had gained as a result of the program. One stated: "I have a better idea of the mathematics that is taught in middle school." Several stated that they felt more confident to teach middle school mathematics. "I feel more comfortable in my ability to do math, therefore, I feel stronger in my love for math and it shows to my students." The teachers also indicated that they felt more comfortable answering student questions concerning mathematics. Two of the participants felt they would be able to present students with a variety of representations for concepts in mathematics.

Although the participants reported feeling more confident and able to present the mathematics to students using a variety of approaches, several statements and the videotapes of their teaching presented conflicting views. When asked how she would feel presenting her students with a problem that did not have one specific answer, one teacher replied, "I would feel very uncomfortable with that problem." Further discussion indicated this teacher still felt unsure of her own ability in mathematics and would not want to give students a problem that she, herself, could not explain in a particular manner. In the videotaped lessons three of the teachers were not able to give the students alternative explanations for a concept; instead they repeated the explanation of the concept.

Implications for Mathematics Education

The purpose of this study was to document the changes that occurred in inservice teachers' knowledge structures as a result of the two-year professional development program. The conceptions/knowledge structures of the teachers in this sample regarding mathematics teaching did not change significantly. It is not surprising that the teachers' knowledge structures of pedagogy had not changed during the program. These teachers were experienced and had established their beliefs about teaching. Most of the teachers stated they believed students learned best with hands-on activities or manipulating concrete materials. This belief was confirmed by the videotaped lessons.

The teachers continued to believe that mathematics was the study of numbers or learning the "basics" followed by application of the concepts to daily life or problem solving situations. The changes that seemed to influence both the teachers' conceptions of mathematics and mathematics teaching was the introduction of the NCTM Curriculum and Evaluation

Standards (1989) and integration. None of the teachers mentioned these standards or integration as important elements of mathematics or its teaching at the beginning of the program, however, most of them mentioned their importance at the end of the program. The teachers also mentioned the importance of integration of mathematics with other subject areas.

Another important impact the program had on these teachers was enhancing their awareness of students' perceptions of mathematics. Perhaps the teachers' own frustration and confusion with the mathematics they themselves were learning in the program made them more aware of the students' feelings, perceptions, and understandings of mathematics. Although not a major goal of the program, this awareness may have impacted how these teachers taught.

The teacher is the critical element for the suggested changes in the mathematics education of our youth. The NCTM Professional Standards (1991) suggests that mathematics teachers in grades five through eight take a minimum of 15 semester hours in college mathematics. Although these teachers were taught additional mathematics, that mathematics was taught separately from the mathematics education courses in this program. Shulman (1986) emphasized that conceptual structures influence learning of subject matter and pedagogy. Simply requiring teachers to take a greater number of mathematics courses at the college level may not be sufficient to overcome the initial conceptions of mathematics and mathematics teaching. The mathematics taught in this program focused on mathematical concepts rather than merging the appropriate methodology. Alternative professional development programs need to be investigated to identify approaches for affecting teacher's conceptual change in mathematics.

Teachers expected to teach mid-level mathematics are prepared by being licensed to teach, however, are not prepared to teach the specific mathematics that is required. The question becomes: How can an intervention in a professional development program meet the needs of a changing mathematics curriculum and pedagogy? Since teachers tend to teach as they were taught, one consideration may be to integrate the mathematics and mathematics education coursework in such a manner that the teachers learn the mathematics in a conceptual, problem solving manner and in manner consistent with the way mathematics should be taught at the mid-level.

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